REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
10/02/2007	Final	09/01/2004-09/30/2006

4. TITLE AND SUBTITLE	
Using a Near-bed Sediment Flux Sensor to Measure Wave Formed Bedform Migration and Formation Processess; A Continuation of ONR Grant N00014-01-1-0564	**5a. CONTRACT NUMBERS**
	5b. GRANT NUMBER N00014-01-1-0564
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Traykovski, Peter A.	**5d. PROJECT NUMBER** 13056400
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
Woods Hole Oceanographic Institution 266 Woods Hole Rd. Woods Hole, MA 02543	

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSORING/MONITORING ACRONYM(S)**
Office of Naval Research One Liberty Center 875 North Randolph Street, Suite 1425 Arlington, VA 22203	ONR
	11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

My research program focuses on identifying and quantifying sediment erosion, transport, and deposition processes on the continental shelf through state of the art observational techniques in both fine grained and sandy environments. In sandy environments, my goal is to understand the detailed interactions and feedbacks between hydrodynamics, bedforms, and the resulting sand transport. In fine-grained environments, I have been investigating the role fluid mud flows as a depositional mechanism in areas with high deposition rates. In both of these types of environments, I have also focused on relating the small-scale transport processes to larger temporal and spatial scale depositional and erosional patterns.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**		6	Peter Traykovski
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Using a near-bed sediment flux sensor to measure wave formed bedform migrations and formation processes

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#N00014-01-10564

LONG-TERM GOALS

My research program focuses on identifying and quantifying sediment erosion, transport, and deposition processes on the continental shelf through state of the art observational techniques in both fine grained and sandy environments. In sandy environments, my goal is to understand the detailed interactions and feedbacks between hydrodynamics, bedforms, and the resulting sand transport. In fine-grained environments, I have been investigating the role fluid mud flows as a depositional mechanism in areas with high deposition rates. In both of these types of environments, I have also focused on relating the small-scale transport processes to larger temporal and spatial scale depositional and erosional patterns.

OBJECTIVES

The primary goals of this work are: 1) To quantify the role of bedload vs. suspended load transport in forming and forcing the migration of wave orbital scale ripples based on measurements from a near-bed suspended and bedload sediment flux sensor. 2) To study the interactions of the forcing hydrodynamics, sand transport processes, and bed geometry by determining how the hydrodynamic wave and current boundary layer structure over the bedforms is modified by the presence of different scale bedforms, and investigating the mechanisms by which bedload and suspended load transport is controlled by the forcing hydrodynamics over the bedforms. This project was also closely related to and conducted at the same time as a mine burial project and a project to study spatial variability of ripple formation processes. Thus the data and analysis form these three projects has considerable overlap

APPROACH

The approach to achieve these objectives combines field measurements, data analysis, and modeling. The field measurements (Figure 1) included measurements of bedform topography on a rapid enough time scale to observe ripple migration and temporal changes in geometry. This was conducted by using a rotary sidescan sonar system and a 2-axis rotary pencil beam sonar. Velocity and suspended sand concentration from the pulse coherent Doppler profiler measurements resolved the wave boundary layer and lower portion of the current boundary layer, thus allowed estimates of sand flux in this region. Most significantly, a near-bed flux measurement allowed investigation of the processes that force bedform formation and migration (Traykovski 1998). The conceptual basis for this type of measurement is that the stationary bed does not produce a Doppler shift and grains moving immediately above the bed, while difficult to resolve spatially from the stationary bed, produce a

measurable Doppler shift. The observational portion of the work took place at the Martha's Vineyard Coastal Observatory (MVCO). A second portion of the observational work was to examine the larger spatial scale variability to bedforms and to relate this to the smaller scale transport processes. This was conducted in conjunction with the mine burial observational program.

The modeling portion of the work combined simple analytical and empirical models along with complex numerical models. The simple modeling included examining the application of steady flow bedload models such as the Meyer-Peter Muller Bedload model to wave forced flow over ripples. The numerical modeling is being conducted in collaboration with H. Jiang at WHOI and involves comparing the observations to Large Eddy Simulation (LES) predictions forced with observed free stream velocities.

WORK COMPLETED

During 2002 a significant amount of laboratory work was conducted in the WHOI 17 m flume to characterize the system. In flume test we examined the use of several bi-static geometries (Figure 1) and processed the data using both pulse-pair and spectral algorithms. This bistatic configuration is similar to that used by Alex Hay in his Coherent Doppler Profiler (CDP) (Zedel and Hay, 1999). This allows measurement of 3 velocity axes and backscattered amplitude to estimate suspended sediment flux over the lower 30-50 cm above the seafloor. Flume tests were performed u with several different flow velocities over a mobile sand bed. A suction sampling system was used 10 cm downstream of acoustic sampling volume to measure in-situ bedload flux during several of the runs. The data from these runs has been examined using both spectral and pulse pair algorithms. The system was also run with a fixed flat bed and a Laser Doppler Velocimeter sampling the same volume as the acoustic system to test the velocity measurement capabilities of the acoustic system.

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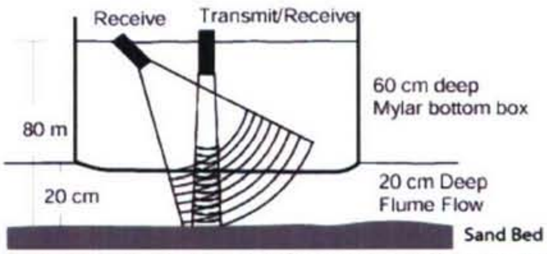

Figure 1. The bi-static geometry used in the flume test allows resolution of both bedload and suspended load fluxes. Due to the 20 cm depth of the flume an acoustically transparent bottom box was installed above the flume to house the transducers in a "field" geometry

The bistatic Doppler system that was developed in 2002 was transitioned into a field deployable system in 2003 (Figure 2). It has been deployed on a quadpod along with a 2-axis pencil beam sonar, a rotary fan beam sonar, and a ADV to measure bedform evolution along with the hydrodynamic and sediment transport forcing processes. In the July of 2003 the system was deployed in coarse sand, which supports large orbital ripples, 100 m from the MVCO node. Unfortunately, cable technical problems and subsequent node failure only allowed 4 bursts of data during active ripple conditions. In December, 2003 the system was redeployed on a short cable, in fine sand near the MVCO node at the same time as the mine burial program was being conducted.

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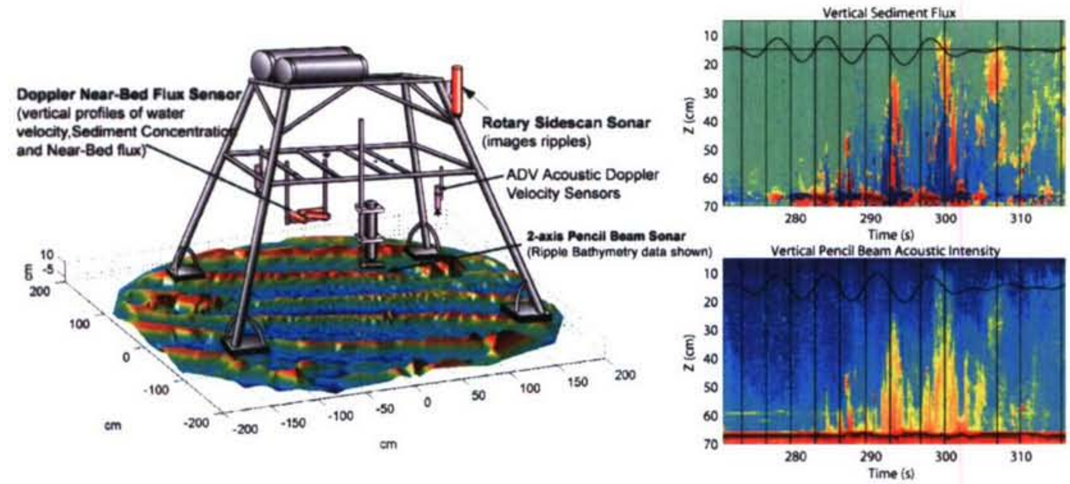

Figure 2. Left: A instrument frame with a 2-axis pencil beam sonar to map ripple bathymetry as shown, a rotary fanbeam sonar to map the larger scale distribution of ripples in the vicinity of the frame, a ADV to measure waves and currents, and bistatic Doppler profiling system to measure near bed sediment flux. Right: Uncalibrated Estimates of vertical sediment flux (top) and concentration (bottom). The elevation of the bed under the sensor on the lower panel varies by 1 to 2 cm coherent with the wave forcing. The vertical flux estimates indicates upward near-bed flux when the bed drops in elevation and near-bed downward flux as the bed increases elevation.

A four month data set with several energetic wave events (over 3 m significant wave height) was recorded during this deployment. In 2004 the system was upgraded with a armored fiberoptic cable to allow access to the coarse sand and avoid the cable failure modes that were previously experienced. The system was successfully deployed in coarse sand from Sept 05 to April 06 and delivered usable data for 80% of that period including several events of over 4 m wave height. The remaining 20% of the data was contaminated by biofouling.

RESULTS

Laboratory Experiments: The mobile sand bed formed bedforms of 5 to 10 cm height and 30 to 40 cm wavelength with nominal flow speeds of 50 cm/s (Figure 3). While the largest scale bedforms were somewhat two dimensional many smaller scale three-dimensional features would form and rapid time-scale variability in flux was visible through the flume viewing windows. In Figure 3 a run is shown where two large bedforms migrated past the sensor and then the bed evolved into a more three dimensional state. High velocity jets are visible in the upper portion of the flow downstream of bedform crests. In the lee of the bedform flow reversal is evident. The scattered intensity also showed some suspended sediment 5 to 8 cm above the bed in the lee of the bedforms. On the upstream side of the bedforms (minutes 3 through 9 and 10 through 14) high scattering intensity was confined to with 1.5 centimeters of the bed. This was consistent with both visual observations, and suction samples 3 cm above the bed were typically three orders of magnitude less than the sample at bed level. The spectral flux estimate shows high flux in the range bin with the highest intensity, or one range bin

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above. Flux was highest in a thin layer on the upstream side of the bedforms. Visual observations indicated that part of this flux would deposit immediately in the lee of the bedform and periodically avalanche down the lee slope and part of the upstream flux would be entrained into suspension in an eddy in the lee of the bedform. The Doppler flux estimates show the suspended sediment flux in the lee of the bedform, but do not appear to resolve the avalanching events.

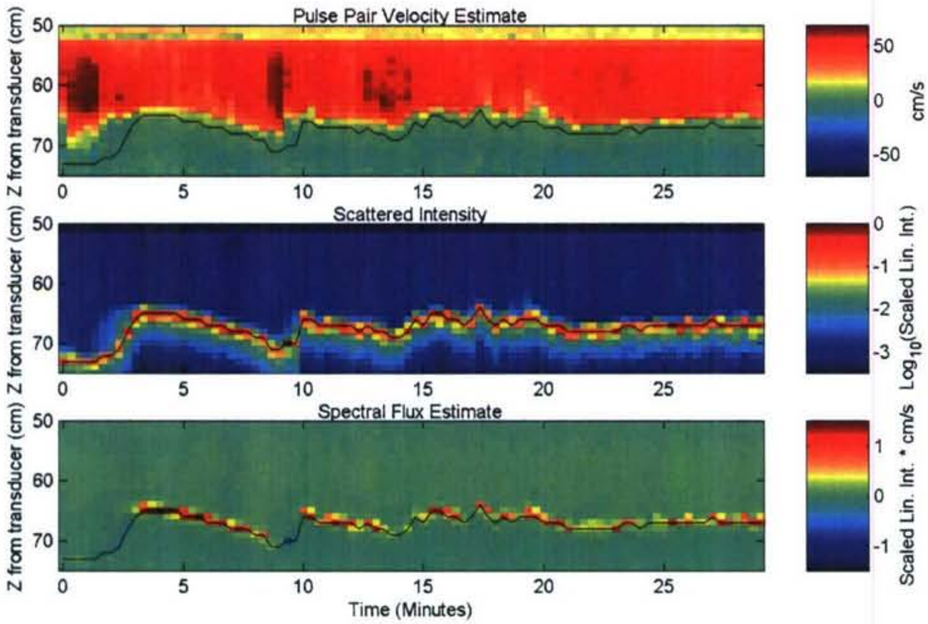

Figure 3. Upper panel: pulse pair velocity estimate with the bed as defined by the range bin with the highest scattered intensity shown as a black line. Middle Panel: Scattered intensity from transmitting on the vertical pencil beam and receiving on the fan beam transducer. Intensity units are linear, and scaled to have a maximum intensity of unity during this run. Lower Panel: Flux estimate using the spectral algorithm.

In Figure 4 results of a comparison between suction samples, flux estimates from bedform migration and the Doppler flux estimate are shown. Due to the fact that small scale three-dimensional features were present on top of the larger more two dimensional bedforms significant temporal averaging was required in the suction samples to averaged this process. However, both time series show the same general trends with high fluxes on the upstream side of the bedforms and lower fluxes in the lee.

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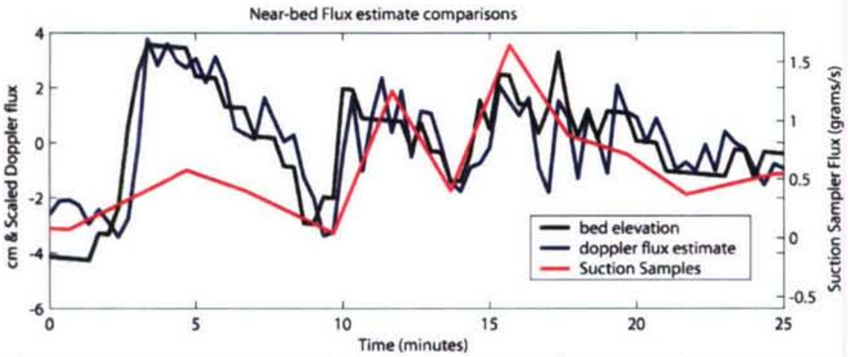

Figure 4. Comparison between the Doppler estimate of nearbed flux, in-situ samples and a flux estimate based on bedform migration.

Analysis of the 2003 coarse sand and 2004 fine data sets focused on comparing the pulse coherent Doppler profiles of velocity, backscatter and sediment flux from the two sites. Not unexpectedly, the data showed that near bed wave-forced flux is the dominant transport mechanism in coarse sand, and that suspended transport is more important in fine sand. In the fine sand both wave-forced suspended net transport components and mean current forced components appear to be important.

Analysis of the 2005 in coarse sand has focused on the temporal evolution of ripple geometry. The data was used to test and calibrate a recently developed time dependent model for ripple evolution. The 2 –axis pencil beam sonar data allows estimation of the wavenumber spectrum of ripple elevation and the model predicts the same quantity. This data set, along with previous rotary sidescan data set from MVCO and LEO-15 show the relict ripple left after storm typical have 0.7 to 1.5 m wavelength. The spectra from the 2-axis sonar data set shows that these relict ripples often have bimodal spectra. While previous ripple models that assume the ripples were in equilibrium with forcing predict short wavelength relict ripples (0.2 to 0.4 m) and unimodal spectra, the temporal delay in the new model allows the model to predict both long wavelength relict ripple and bimodal spectra (Figure 2)

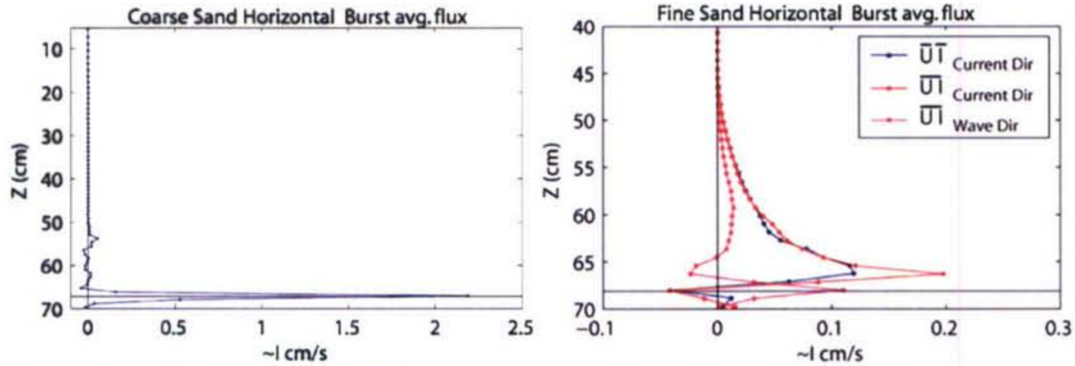

Figure 1. Horizontal flux estimates from coarse (left) and fine (right) sand beds near the MVCO node. In the coarse sand the flux is occurs with 1 cm of the bed and is predominately wave forced. In the fine sand the flux occurs with 20 cm of the bed and has both wave and mean current contributions.

IMPACT/APPLICATION

The ability to measure flux in the vicinity of stationary bed has potential to increase our understanding of bedform processes. Over bedforms basic modes and directions of wave-forced sediment are poorly understood. For instance, the transition from onshore bedload dominated flux to offshore suspended flux has not been well quantified. The role of mean current forced along-shore bedload over bedforms in wave dominated flows has also not been measured well as there is often not a ripple migration signal associated with this transport mode. This type of measurement has potential to address these issues.

RELATED PROJECTS

This project is closely related to several projects associated with the mine burial prediction program as this data set was collected at the time as a major mine burial experiment at MVCO. This data set provides background bedform measurements in absence of mines. It is also closely related to projects that are aimed at understanding the ripple scour depressions (RSDs) at MVCO. The small scale transport process observations that this system provides can be used to aid in conceptual and numerical models of RSDs.

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